

Sesame Cultivation in Water-Deficit Conditions

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This study aimed to develop effective sesame cultivation technology for the water-scarce and saline conditions of northern Karakalpakstan. Field experiments were conducted using four locally adapted sesame varieties - Tashkent-122, Khiva, Sadaf, and Kara Shahzoda - under varying irrigation regimes. Drip irrigation and a combination of organic and mineral fertilizers were applied on meadow-alluvial soils with moderate salinity. Soil nutrient dynamics, plant growth parameters, and yield components were analyzed. Results showed that water deficit conditions altered soil nutrient availability, particularly increasing residual nitrogen and potassium levels due to reduced nutrient uptake by plants. Among the tested varieties, Tashkent-122 demonstrated superior performance in plant height, pod and grain number, seed weight, and overall yield, making it the most suitable for arid environments. These findings highlight the potential of water-saving technologies and appropriate varietal selection to enhance sesame productivity in saline, low-water agroecosystems.

Keywords: Abiotic stress, climate change, water stress, water-saving technology, soil degradation, drought-resistant, soil salinization, oilseed crops, yield.

INTRODUCTION

The drying of the Aral Sea and ongoing climate change have led to intensified soil degradation in the agricultural zones of northern Karakalpakstan, particularly through increased salinity. The flow of the Amu Darya River is decreasing, which has led to an acute shortage of water resources in its lower reaches. Farmers and peasants are forced to adapt to the current unfavorable conditions and gradually switch to growing less water-consuming crops (Kenebayev et al., 2022; Feng et al., 2024). In recent years, due to the disruption of the ecological balance in the Republic of Karakalpakstan, the yield of cotton, the main crop for this area, has been declining (Zain-Ul-Hudda et al., 2024). In this regard, a government resolution was adopted to ensure the sustainable development of agricultural production. In this resolution the cultivation of drought-resistant food crops has been stressed (Pongprayoon et al., 2025).

Calculations show that the Republic of Uzbekistan has great potential for a significant increase in the production of oilseed crops, the sown area of which is growing due to water shortage. One such promising culture may be claimed sesame. The increase in gross grain harvest of oilseed crops in the Republic will be due to some expansion of sown areas on the mainlands, but mainly as a result of high productivity. To add more, environmental factors have a special impact on different varieties of cultivated crops. Since, the peculiarity of the climate of Karakalpakstan is in its sharp continentality, what poses extremely difficult problems for agriculture (Suraganov et al., 2024). The soil is not homogenous and may be characterized by the predominance of saline and low-fertility lands, as well as the limitation of irrigated agriculture areas (Nurgaziev et al., 2024). Meadow alluvial soils are widespread in all regions of the Republic of Karakalpakstan. Of the total irrigated area, 37 percent of the lands are moderately saline, 35 percent are highly saline, and 28 percent

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are slightly saline. The depth of groundwater and its mineralization have a great influence on soil salinization (Nugmanov et al., 2024). All this requires a radical revision of the farming system at a modern level to meet the needs of the population for food and vegetable oil.

Based on this, there is a need for scientific research on the selection of drought-resistant crops that require less water, and the development of resource-saving technologies on saline lands and in conditions of water deficiency. Currently, the introduction of new types of crops into agricultural production is one of the most important factors in increasing productivity. Therefore, their correct selection and introduction to large areas is the main direction of agricultural development (Mambetnazarov et al., 2024a). When selecting varieties, preference should be given to those varieties bred in the conditions of Karakalpakstan, adapted to the soil and climatic conditions of the zone. When propagating seeds of new varieties, it is necessary to pay attention to the melioration state of the land. When developing new varieties, the best local and ancient varieties resistant to stress factors, as well as diseases and pests, can be used as source material (Nurmatov et al., 2012).

Resource-saving technologies play an important role in preserving moisture and increasing soil fertility. Well and deeply processed soil helps to create a powerful root system of agricultural plants, thanks to which they more easily absorb water and food. Soil cultivation creates a favorable structure of the arable layer, capable of accumulating and preserving moisture, air and nutrients in the right quantities and the best ratios (Corsi, 2019).

Today, sesame is one of the main oil plants and is widely cultivated in more than forty countries around the world. The largest quantities of sesame seeds are grown in Burma, India and China, and these countries account for about 50% of world production (Azizov, 2008).

Grain yield depends on the number of plants per unit area, the number of pods and grains per plant, and the weight of 1000 grains. Optimal fertilization with nitrogen, phosphorus, and potassium fertilizers has a significant impact on the above plant characteristics (Amanova et al., 2018). The high weight of 1000 sesame seeds is an important indicator in determining the yield (Amanova and Allanazarova, 2017).

The resistance of plants sprouted from large grains to unfavorable environmental conditions is also crucial. Sesame has such a peculiarity that when sowing seeds of sesame varieties at the optimal rate the grain yield and grain quality indicators are high (Mambetnazarov et al., 2024b).

To obtain high yields, plants must be provided with the necessary living conditions in certain combinations and quantities at each stage of growth and development. In production, it is not always possible to satisfy the needs of plants in all life factors at the same time. In most cases, the life factor that is in the first minimum is the leading one in

these soil and climatic conditions. In arid areas, it is water (Nurbekov et al., 2013).

Organic and mineral fertilizers affect the structure of the soil, the reaction of the soil solution, the intensity of microbiological processes, actively participating in increasing soil fertility. Such soils are characterized by lower acidity, a large amount of phosphoric acid available to plants, increased humus content and greater absorption capacity (Kosinsky & Rubanov, 1980).

The Government of Uzbekistan has initiated crop diversification activities: the area under cotton has been significantly reduced to increase the area under food crops. Given high population growth rates, land degradation and climate change, higher value crops and value chains seem preferable for ensuring food security in the coming decades (Christman et al., 2009; Begmatov et al., 2020; Matyakubov et al., 2021a).

The farming system cannot be the same everywhere, it has a zonal character, and the methods of agricultural technology, the system of fertilizers can change even in one zone depending on weather conditions. Therefore, the methods, timing and methods of applying fertilizers, the ratio of nutrients in them will depend not only on the crop and soil, but also on climatic, weather conditions, the temperature regime of the soil, the atmosphere, etc. (Pannikov & Mineev, 1987; Matyakubov et al., 2021b; Rahmatov et al., 2021; Avlakulov et al., 2023; Pulatov et al., 2024; Burkhonova et al., 2024a; Burkhonova et al., 2024b).

Given the increasing challenges of water scarcity, soil salinization, and climatic instability in the northern regions of Karakalpakstan, there is an urgent need to identify drought-resistant crops and develop adaptive cultivation strategies. Sesame, as a low-water-demanding oilseed crop, presents a promising alternative.

Thus, the purpose of our research is the development of sesame cultivation technology in the conditions of the northern regions of Karakalpakstan, using soil-protective, resource-saving technology methods.

MATERIALS AND METHODS

Place of the experiment: The soil of the experimental plot is of the meadow-alluvial type, long-standing irrigation (experimental farm of the Research Institute of Agriculture of the Chimbay District of the Republic of Karakalpakstan). Before sowing, flushing irrigation was carried out twice, in April (2500 and 2200 m³). After flushing the field, 70% of phosphorus and potassium and 20% of nitrogen fertilizers were applied before plowing. All technological methods in the experimental field were carried out on the basis of the general technology adopted in the region.

In most cases, old irrigated soils are saline to varying degrees to a depth of 1.5-2.0 m. The amount of humus is 0.4-0.6%, and the amount of food elements is correspondingly small.



Table 1. Mechanical composition of the experimental field soil.

Soil layer, cm	Soil particles, mm								Named according to its mechanical composition
	>0.25	0.25-0.10	0.10-0.05	0.05-0.01	0.01-0.005	0.005-0.001	<0.001	<0.01	
0-30	1.04	3.2	7.3	32.0	10.1	15.6	16.3	36.5	average
30-50	1.61	3.0	5.3	28.3	12.3	16.5	17.3	46.1	heavy sand
50-80	1.01	2.1	8.3	64.4	5.8	8.7	10.7	25.2	light sand
80-120	1.36	5.6	12.1	62.2	4.1	7.0	9.0	20.1	sand
120-160	1.51	2.5	9.3	61.7	6.3	8.1	12.1	26.5	light sand
160-200	1.78	8.7	14.5	58.1	3.4	5.7	9.6	18.7	sand

As can be seen from Table 1, the upper soil layer (0-30 cm) is salinized to a lesser extent (the amount of dry residue is 0.1-0.3%), the number of salts increases as you move into the lower layers (1.0-1.5%).

The climate of Karakalpakstan is continental, unstable by years and seasons, in general, the area of insufficient moisture (Schlubach, 2021; Makhmudova et al., 2023). Precipitation in most years is not enough for normal growth and development of plants. It falls unevenly. Soil conditions are also characterized by great diversity and prevalence of saline and unsuitable lands. In the nature of distribution and intensity of manifestation of meteorological factors, instability is observed by years, and sometimes during the vegetation period, which is obviously caused by serious changes in ecology.

Due to the lack of irrigation water, in recent years in our region, the yields of all agricultural crops have significantly decreased. Therefore, it was necessary to find ways to solve these problems. Of particular value as a source material for the harsh conditions of Karakalpakstan can be samples that stand out for their early maturity, drought resistance and productivity. For this purpose, we began a study on drought-resistant crops - like sesame.

Instruments: Irrigation rates were measured using a Chip poletti water meter with a threshold width of 0.5m.

The quantities of fertilizers are: NO_3 was 1.16-3.75 mg/kg, P_2O_5 - 1.04-4.01 mg/kg, K_2O - 193.3-320.0mg/kg.

High-quality seed preparation is important for growing a good harvest of agricultural crops. Therefore, the seeds were treated with fungicide against pests and diseases 20-25 days before sowing.

Samples of seeds: For testing, varieties bred in local conditions were selected, such as Tashkent-122, Khiva, Sadaf and Kara Shahzoda.

Stages of the experiment: The experimental variants were placed in 3 tiers, the area of each plot was 240 m², of which the estimated area was 120 m². In the experiment, phenological observations, calculations and laboratory analyses were carried out according to the methodology of the State Commission for Testing Agricultural Crops (1989).

To determine the optimal amount of moisture in the soil, timing and rate of irrigation, soil samples were taken every 3-

5 days at a depth of 1m and the soil moisture was determined by drying using a drying cabinet.

RESULTS

By the end of the growing season, it was observed that the amount of humus, total nitrogen, phosphorus and potassium, as well as nitrate nitrogen, changed in the soil depending on the water deficit. With a deficit and irrigation method, an increase in the amount of total nitrogen was observed, and the amount of potassium was 1.50%, and for the corresponding options this amount was 1.61-1.78%. It was found that the reason is that the nutrition of the sesame plant decreased due to a lack of moisture, and its amount increased as a result of the inability to use nutrients.

It was observed that the nutrient content of the water-deficient soil improved, especially the total nitrogen and phosphorus content. The amount of total nitrogen became acceptable as the water deficit decreased and the amount of phosphorus and potassium increased.

By the end of the growing season, an increase in the amount of total nitrogen was observed, and the amount of potassium was 1.50%, and for the corresponding options this amount was 1.61-1.78%. This occurred because the sesame plants absorbed fewer nutrients due to moisture deficiency, leading to an accumulation of unused nutrients in the soil.

It was observed that the nutrient content of the soil with water deficit improved, especially the total nitrogen and phosphorus content. The amount of total nitrogen became acceptable as the water deficit decreased and the amount of phosphorus and potassium increased. By the end of the growing season, the soil of the experimental plot will move into the group of soils with low nutrient supply. Since, the agrochemical properties of the soil change depending on the moisture content of the soil, the method and frequency of irrigation.

As shown by the data as of September 1, there was no significant difference in plant height between the varieties. The height of the plants was within the range of 104-115 cm. In terms of height, the Tashkent-122 variety was taller than the others and averaged 115 cm.

There were significant differences in the yield of commercial grain among the varieties (Table 2). Because, if we consider that 50 to 100 seeds are formed in one pod, then 5-10 pods



will contain more than 700-800 seeds. As shown in the table, the number of pods among the varieties varied from 3 to 9 pcs. per plant. The Khiva and Tashkent-122 varieties formed an average of 46-50 pods in one plant, while the Kara Shahzoda and Sadaf varieties formed 41-44 pods. If we analyze the number of grains in one pod, the varieties Tashkent-122 and Kara Shakhzoda had on average 60-64 grains in a pod, and the varieties Sadaf and Khiva - 57-58 grains. This means that the yield will be significantly reduced.

Table 2. Vegetation period and yield elements of sesame varieties.

Experience options	Plant height, cm	Number of pods per plant, pcs	Number of grains in a pod, pcs
Kara Shahzoda	104,0	44	59
Sadaf	108,0	41	58
Khiva	110,0	46	60
Tashkent-122	115,0	50	64

The weight of 1000 grains are the main characteristic that determines the size of seeds and yield. As shown in Table 2, there was no significant difference between varieties in the weight of 1000 grains, but the Tashkent-122 variety had 0.2-0.4 grams more than other varieties (Table 3)

The productivity indicators of the plant mainly depend on the density of plant standing, grain size and the number of grains per plant. It is evident that the Tashkent-122 variety provided the highest productivity. Here, the density of standing, plants, 1000-grain weight, number of pods and grains per plant are significantly higher than those of other varieties, therefore, it provided the highest yield. Here, the Sadaf variety is equal to the Tashkent-122 variety in the number of plants, but the Sadaf variety is significantly inferior in the number of pods per plant and the number of grains in a pod. Therefore, it yielded less than 2 centners of yield per hectare. The Kara Shahzoda and Khiva varieties are close to each other in the number of plants and 1000-grain weight, they differ slightly in the number of pods per plant and the number of grains in a pod. But still, the Khiva variety yielded 2 centners more than the Kara Shahzoda variety per plant and the number of grains in the pod. Therefore, it yielded less than 2 centners of yield per hectare. The Kara Shahzoda and Khiva varieties are close to each other in the number of plants and the weight of 1000

grains; they slightly differ in the number of pods per plant and the number of grains per pod.

However, the Khiva variety yielded 2 centners more than the Kara Shahzoda variety.

Three years of research showed that when growing sesame, you can limit yourself to one watering. If you use drip irrigation, then the economic benefit will be even greater.

Cultivation of sesame in conditions of water deficit gives a tangible result. Since, late sowing period, short vegetation period, unpretentiousness of care, little demanding watering, all these qualities are highly valued in agriculture.

DISCUSSION

This study examines the water regime, nutrition, and yield of different varieties of sesame under different water supply conditions. It aligns with recent studies focused on improving cultivation of crops and water efficiency in arid and semi-arid regions (Jabeen et al., 2021; Alharbi et al., 2024). Due to its late sowing period, short vegetative period, low maintenance requirements, and minimal watering requirements, sesame cultivation under water deficit conditions yields measurable results.

The results indicating changes in soil nutrients due to water deficit align with the study of Bhattacharya (2021), who concluded that soil water deficit affected mineral nutrient relations, inhibiting plant growth because there is a reduction in mass flow-dependent mineral nutrient uptake and the translocation of soil nutrients from the roots to the shoot. Patra et al. (2022) also agreed that absorbed nutrients were reduced in water deficit conditions, suggesting the implementation of hydrogels as suitable alternatives. The disparity in the amount of nitrogen and potassium in water deficit conditions aligns with recent studies that conclude that water deficit or drought stress reduces the absorption of nitrogen, potassium, and phosphorus (Salem et al., 2022; Chowdhury et al., 2024). This scenario pinpoints the difficulties associated with using NPK fertilizers in water-deficit areas and a need for efficient irrigation systems or alternative fertilizers.

The results on the plant yield and water deficit align with the studies of Bhattacharya (2021a) and Hafez et al. (2021), who concluded that there was a notable decrease in plant yield in soil water deficit conditions. The results show that the 'Tashkent-122 variety of sesame produced outstanding results in plant height, number of pods and grains, plant density, and

Table 3. Plant density and yield indicators.

No.	Experience options	Number of plants (thousand/ha)	Growing season (days)	Weight 1000 grains (g)	Productivity (kg/ha)
1	Qara Shahzoda	180	113	3.0	1350
2	Sadaf	184	115	3.2	1380
3	Khiva	182	111	3.1	1370
4	Tashkent-122	184	110	3.4	1580



growth rate, presenting it as economically viable and optimal for cultivating in arid regions. Khiva varieties, though slightly inferior to Tashkent-122, can also be widely cultivated to increase variety and prevent oversaturation (Isabaev et al., 2024).

A limitation in this study lies in the lack of variety; future studies should be focused on comparing the effect of fertilizers on sesame plant heights in water deficit conditions and in conditions without fertilizers to make conclusive conclusions (Soltanbeigi et al., 2021). Further research is needed to provide alternative ways of improving soil nutrients in ways that they can be easily absorbed by plants. Studies like Kazemalilou et al. (2021), which explored applying organic and inorganic fertilizers to increase plant tolerance to water deficit, can be expounded upon for sesame plants. The present study focuses on drip irrigation, leaving a gap for other irrigation methods to be studied in growing sesame plants. The molecular and genetic morphology of Tashkent-122 should be studied to provide a comprehensive understanding of the genes responsible for the significant results and also to provide primary materials for cross-breeding (Sravanthi et al., 2021).

Conclusion: The correct selection of varieties for each region, the use of the best seeds for sowing, a combination of crop rotation and advanced cultivation technology allow us to obtain a high-quality harvest. As is known, not all varieties equally use the conditions created during their cultivation. Some of them by their nature are not capable of giving high productivity at all, being low-yielding, others being susceptible to various diseases or unstable against unfavorable weather conditions, also cannot give high yields. For production, the most valuable varieties are those capable of giving stable yields in a given area. The scientific significance of the research results lies in the fact that the use of drip irrigation in conditions of water deficit, on moderately saline meadow soils, has a positive effect on the yield and quality of grain, which is explained by its correct scientific justification.

CRedit author statement: Bisenbay Mambetnazarov conceptualized and supervised the research. Biysenbay

Bekbanov and Amangeldi Mambetnazarov designed and executed field experiments. Bakhitbay Aybergenov and Shaxzada Kuanishbaeva carried out data collection and laboratory analysis. Asan Mambetnazarov performed statistical analysis. Bakhit Mambetnazarov contributed to writing and editing the manuscript. All authors read and approved the final version of the manuscript.

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SDGs addressed: Zero Hunger; Clean Water and Sanitation; Responsible Consumption and Production; Climate Action.

Policy referred: Climate-Resilient Agriculture Policies; Efficient Water Use and Irrigation Policies

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